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ABSTRACT

Different aspects of text comprehension and different evaluation procedures were studied for elementary school students. Indicators sensitive to the different levels of comprehension involved were used, and recall was divided into recall macro, micro, and total. The sample consisted of 90 sixth graders in the national capital region of Canada. Relationships among the results of a free, written recall protocol, a questionnaire, and problem-solving activities were examined as they allowed the observation of different text processing levels. The problem-solving activities measured something different than the recall task and questionnaire measures; no significant correlations were obtained between these activities and other variables in the study. The questionnaire did not measure exactly what the recall task measured, and the recall task appeared more sensitive to the effects of test type and domain knowledge. Overall, the recall task was a more discerning performance measure. The recall task and the problem-solving activities appear to be the most promising approaches for constructing a reading comprehension text for sixth-grade native speakers of French. Three bar graphs and two tables present study data. (Contains 19 references.) (SLD)

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COGNITIVE PROCESSES IN READING AND EVALUATION PROCEDURES

Patricia M. Raymond, Jean-Paul Dionne, Jean-Yves Boyer,
Andre'-Jacques Deschenes and Michel Page'

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Cognitive processes in reading and evaluation procedures

Patricia M. Raymond, Jean-Paul Dionne, Jean-Yves Boyer, André-Jacques Deschênes and Michel Pagé

Theoretical Framework

Kintsch (1994) has distinguished between remembering a text and learning from it. Memory for text means that one can reproduce it in some "form more or less verbatim, and more or less completely, at least its gist" (p. 294). This reproduction can involve free recall or summary writing. It may be at a very superficial level of understanding. Learning, on the other hand, requires the integration of text information with one's background knowledge. It goes beyond the text itself in that one can use the information provided by the text to infer new facts, or in conjunction with previous knowledge to solve problems, or to answer inference questions after reading a text. In this way, learning is considered to be reconstruction involving deep understanding.

According to Kintsch (1994) text comprehension is information processing, and involves surface level components such as words and phrases, a semantic and rhetorical structure, and a situation model which interprets meaning. More precisely, comprehension involves construction and integration. The construction of a textbase includes three levels of information processing. The first consists in deciphering the surface elements and words of a text. Each element is then elaborated, propositions are added and connection strengths are assigned to all pairs of elements created in this microstructure or second level of construction. The third level of the textbase contains the macrostructure or gist of the text obtained through the deletion, generalization, construction and carry-over of certain propositions (Kintsch and van Dijk 1978; van Dijk and Kintsch, 1983). The macrostructure, which is built from the microstructure, contains a text's global organization into main and subordinate points. The textbase thus represents the meaning and structure of the text as a network of propositions. It enables the reader to reproduce the text, i.e., to recall it or to summarize it. The integration

phase aims at integrating the textbase with the reader's background knowledge (level four). In this situation model or mental model, the information provided by the text is elaborated from background knowledge and is integrated with it. At this point, the textbase contains not only a mental representation of the event(s) and individual(s) described in the text itself but also of all previous experiences, textbases and the general knowledge of the reader. It represents the content of the text as it is integrated with the reader's background knowledge. Comprehension typically involves the formation of a mental model of the situation described by the text (Kintsch, 1992). The situation model allows the reader to use the information acquired from the text to make inferences, to elaborate on the text, or to solve problems, etc.

Thus, in the Kintsch model (1988), there are four levels of information processing or comprehension and four types of memory representation (linguistic or surface, microstructure or local, macrostructure or global and situational).

E. Kintsch (1990) and Kintsch and Kintsch (1991) have associated these four types of memory representation with different evaluation procedures. For example, a summary writing task and a free recall task both reflect the organization of information in memory and refer to the microstructural and the macrostructural levels. They depend on the quality of the textbase. Problem-solving involves the situation model, an interpretation of the situation described by the text. In this way, different evaluation procedures depend on different forms of memory representation.

These findings resulted from a study by Mannes and Kintsch (1987) in which subjects were given background knowledge material in the form of an outline before actually reading an experimental text. This background knowledge material was organized either consistently or inconsistently with the structure of the text. When the background knowledge material was presented in its consistent form, university level subjects were better able to remember the text than when it was presented in its inconsistent form. And this held true for both a free recall and a sentence verification task. But in the inconsistent outline condition, subjects did better on

inference statements and a problem-solving task. Mannes and Kintsch stated that with the consistent outline form, subjects did not need to elaborate a complex situation model because the macrostructure of the text fit well into the structure already formed for the background knowledge material. Thus, their memory for text, which depended on the textbase, was good. And this explains their superior results on both the free recall and sentence verification tasks. but inferencing and problem-solving, which depend on the situation model, were not as good. With the inconsistent outline form, a discrepancy in the organization of the background knowledge material and that of the target text required the subjects to form a new macrostructure--with interference from the old text structure. Thus, recall was not as good. But the mental representation of the text was more interconnected with other parts of the background knowledge material allowing easier access to this material. Subjects had to elaborate a complex situation model and thus, they achieved better results on inference statements and a problem-solving task which depended on it.

That a reader's background knowledge is essential for text comprehension is a truism. The form of a text is also a part of this background knowledge. This form, or semantic macrostructure (van Dijk and Kintsch, 1983, p.241) is learned. The authors state that they do not know to what extent readers have conscious knowledge about semantic macrostructures, but they assume that they have learned them after all their reading experiences during their adult life (pp. 16, 48, 54, 252). Examples of these semantic macrostructures include stories, news discourse and reports. A report, for example, is conventionally organized into an introduction, method, results and discussion sections.

The purpose of the present research was to study the different aspects of text comprehension (based on the Kintsch model (1988, 1992) and different evaluation procedures. Because of the different levels of comprehension involved, indicators sensitive to these levels (macrostructure, microstructure, situation model) had to be used. Because the recall task reflects the organization of information in memory at

both the macrostructural and microstructural levels, recall could be divided into Recall Macro and Recall micro and Recall total. Problem-solving activities were included since they involve the situation model. A questionnaire whose answers depend on information found at both the macrostructural and microstructural levels was included as a basis for comparison with the recall task. This questionnaire was also divided into Questionnaire Macro and Questionnaire micro and Questionnaire total. Our hypotheses for this research were :

H_1 :There is a low correlation between problem-solving activities and Recall Macro as well as with Recall micro and Recall total, and a medium correlation between Recall Macro and Recall micro.

H_2 : There is a high correlation between Recall micro and Questionnaire micro and also between Recall Macro and Questionnaire Macro, but the correlation between Questionnaire Macro and Questionnaire total should be moderate.

H_3 : There are low correlations between problem-solving and each of Questionnaire Macro, Questionnaire micro and Questionnaire total.

H_4 : Text type has an effect on recall, problem-solving, and question answering.

H_5: (exploratory hypothesis) There is a moderate to high correlation between background knowledge and all of the other variables.

Subjects

Sample:

The sample consisted of 90 sixth graders (45 girls, 45 boys, mean age 11 years) from two school boards in the national capital region of Canada. Sixth grade teachers individually ranked each student (1 strong, 2 average, 3 weak) as to reading ability for sixth graders. Intact classes were used. The schools involved represented similar socio-economic areas.[1]

Procedures

Pre-experimental :

Each subject was given a booklet which included a cover sheet and instructions for a background knowledge or domain knowledge test. The testing team read the

instructions aloud as the subjects read them silently. A practice item was included. The subjects completed this test in the allotted time.

Experiment Proper :

One to three days after the domain knowledge test, each subject received another booklet containing a text to read, instructions for completing a free, written recall of this text, for problem-solving activities and for a questionnaire on this text. This task order was counterbalanced across subjects. All tasks were completed in the allotted times.[2]

Post-experimental :

One to three days later, each subject completed the same domain knowledge test as in the pre-experimentation but without the practice item.

Materials

Texts:

The researchers wrote two texts for the purposes of the experiment. The researchers chose the topic "beluga" because it did not appear in textbooks for sixth grade students. Additionally, teachers who had previously ranked the subjects according to their reading ability were consulted; they found the topic and texts to be of interest to and suitable for sixth graders.

In previous research (Boyer, Dionne and Raymond, 1993) it was found that Meyer's system (1975, 1985) was the most frequently used in teaching and learning studies on reading. Using Meyer's system of text classification and information obtained from the Canadian Ministry of Fisheries and Oceans, the researchers wrote one text on belugas in a cause- effect rhetorical structure. This text contains 915 words. In order to control for possible effects of text type, a second text on belugas was written in a collection (sequence) rhetorical structure; it contains 921 words. The sequence and causation texts contain 551 and 552 idea units respectively with 90% of these units remaining common to these two texts. The readability levels of both texts are the same (42 and 44, or of standard difficulty according to the Henry formula (1975) which states that texts written in French

and falling between 35 and 45 are within a zone of optimal readability.)

In a recent study, Moravcsik and Kintsch (1993) found that university level subjects could form more coherent, better organized textbases for recall after listening if the texts used for the listening passages were well written. Kintsch and van Dijk (1978, p. 376) outlined three characteristics of texts to be used for recall purposes. Firstly, they must be sufficiently long to ensure the involvement of macroprocesses in comprehension. Secondly, they must have a clear rhetorical structure. Thirdly, they must be understandable without technical knowledge. The texts used in the experimentation were written to meet these characteristics.

Domain Knowledge Test:

The researchers formulated a test to elicit domain knowledge for the topic, belugas. This test is a free word association form based on Langer (1980) and Hare (1982) which requires subjects to list all the information they know about belugas through the mention of four key words chosen from the text to be read. These key words were chosen on the basis of their frequent appearance in the macrostructure of each text. Each key word was repeated at least ten times down the left border leaving space for the subject to write related terms (Jonassen, Beissner and Yacci, 1993).

This type of free word association task is often used to estimate the domain knowledge of subjects. The underlying theory for the use of a word association task assumes that knowledge concepts are organized in networks and that by activating one concept, other associated concepts become available. The more domain knowledge a reader possesses, the easier it is to associate concepts to the key words chosen for activation. From such a task, both quantitative and qualitative measures which allot points per word associated with the key word can be obtained (Hare, 1982; Langer, 1980).

Questionnaire:

The comprehension questions are in multiple-choice format for each text. Each question consists of a stem, three distractors and a key. The questions are directed

at the word, sentence, paragraph and situational levels. At the word level, questions are based on literal information found in the same sentence as the unknown word or on information found in adjacent sentences. Several inference questions are also included at this level. At the sentence level, questions focus on pronoun reference (subject, object, possessive), demonstratives, synonyms, ellipted items and on paraphrasing parts of sentences. Other types of questions at this level include information on how one sentence elaborates on, contrasts with, presents an example of previously stated information, etc. At the paragraph and whole text levels, questions concentrate on how one sentence or group of sentences best summarizes one paragraph, several paragraphs or the entire text. (For further details see Pagé and Drolet, 1994).

Problem-solving Activities :

The four problem-solving activities go beyond the microstructural and macrostructural levels of the text and are designed to tap into the situation model. These problem-solving activities enable the researchers to estimate how much information from the text is integrated with subjects' background knowledge. The general idea is that confronted with a cognitive task, a person constructs a mental model of the task and its conditions and infers directions for activity from this same model. Within the context of previous research and theory (Richard, 1990, Tardif, 1992), each problem-solving activity has four components: an initial situation, proposed solutions, a procedure which allows the subject to go from the initial situation to the solution and obstacles to the solution. In each activity, other than specific information provided in the text they read, subjects were familiar with the problem described. Additionally, three of these problem solving activities require subjects to visualize a particular problem situation and one includes a picture. The fourth activity is a logical problem.

Scoring Procedures

Recall Protocols:

Each of the texts on belugas was propositionalized according to Meyer (1985).

Each recall protocol was then scored against the content structure (the hierarchical organization of all the idea units in the text) for the total number of idea units recalled. The highest levels in this content structure include the top-level structure and the macrostructure (Meyer, 1985). Idea units found in these first levels (1-3) were termed Macro idea units while those occurring in levels 4 to 8 were termed micro idea units. The correction team (of four) met to discuss scoring procedures, to score five recalls together, and to standardize scoring procedures. At this time, a list of acceptable paraphrases for idea units was formed. Then, ten recalls were blindly chosen, and each corrector scored each one independently. The team met again to settle remaining differences and to make changes to the acceptable paraphrases list. Each recall was then independently scored by three correctors. Any discrepancies were settled by the fourth corrector. A consensus was thus obtained for each recall protocol.

Questionnaire :

There was one correct answer per question. Questions were classified as belonging to Macro or micro levels depending on whether they dealt with information found in the first 3 levels or in levels 4 to 8 of the content structure. All 23 original questions for each questionnaire were submitted to a panel of experts who, after having studied the factorial analysis of these questions, eliminated six of them either because they were ambiguous or because their Macro and micro levels were not identical from one text to the other. In each questionnaire, seven questions were found to be at the Macro level and ten at the micro level. There were thus 17 questions in each questionnaire for the 90 subjects.

Problem-solving Activities:

These were scored with a correction key.

Domain Knowledge Test:

Levels of domain knowledge assigned to the free association responses were categorized and weighted from 3 to 1 with 3 representing much domain knowledge, 2, some and 1, little (Langer, 1980). The scores for the responses to the 4 key words for the beluga were then aggregated.

Results

This research examined the relationships among the results of a free, written recall protocol, a questionnaire, and problem-solving activities as they allowed the observation of different text-processing levels as given in Kintsch (1988, 1992). The research was quasi-experimental. The independent variables were reading ability (strong, average, weak) and two types of expository texts, one in a seq ence rhetorical structure and one in a causation rhetorical structure. The dependent variable was reading comprehension operationally defined as the scores obtained from a recall protocol, a questionnaire, and problem-solving activities. Since the co-variable, domain knowledge was not significantly correlated with the other variables, its adjustment effect was negligible.

Descriptive Statistics

Descriptive statistics for the domain knowledge test, the recall protocols, the problem-solving activities and the questionnaire are presented in bar graphs and in TABLE I

Three bar graphs (Q, R and P/S) display the means for the six combinations of text type (sequence or causation) and reading ability (strong, average and weak).

Insert bar graphs about here.

In bar graph Q, the results of the Questionnaire are presented. There were 17 questions in each questionnaire. As expected, the means for the strong subjects for both texts are the highest (M = 13.78 (sequence) and M = 12.67 (causation) while those for the weak subjects (M = 6.92 (sequence) and 6.80 (causation) are the lowest. Both groups seemed to find the sequence questionnaire easier than the causation questionnaire.

In bar graph R, the results of the recall scores are displayed. Note that maximum possible recall for texts was 551 idea units for the sequence text and 552 for the causation text. It can be seen that the means for the strong subjects for both

texts are the highest (M = 75.11 (sequence) and M = 77.92 (causation) whereas those for the weak subjects (M = 46.83 (sequence) and M = 39 (causation) are lower, again as expected. Note also that the mean for the strong subjects is higher for the causation text, but that the mean for weak subjects is higher for the sequence text. Weak subjects recalled fewer idea units from the causation text.

In bar graph P/S, the results of the problem-solving activities are shown. It can be seen that the means for the strong subjects are not significantly different for the causation text (M = 1.88) and the sequence text (M = 1.83). However, it is interesting that the mean for the weak subjects for the causation text is the highest (M = 1.96) though not significant.

Pearson correlations for all pairs of variables for both texts are presented in Table I. Note that the upper diagonal in this table presents the correlations for the sequence text whereas the lower diagonal presents those for the causation text.

Insert Table I about here.

What is immediately apparent for both texts is the lack of correlations between the problem-solving activities and all of the other variables. This result was expected since problem-solving activities do not measure reproductive recall (Kintsch, 1988, 1992). A moderate correlation exists between Recall micro and Recall Macro for the sequence text (0.65, $p < .001$) as well as for the causation text (0.50, $p < .01$). From H_1 low correlations were expected between the problem-solving activities and each of Recall micro, Recall Macro, and Recall total and a medium correlation between Recall Macro and Recall micro. Thus H_1 and H_3 are confirmed. (See Table I).

As far as H_2 is concerned, in the sequence text, the highest correlations occur between the Questionnaire and the Questionnaire Macro (0.84, $p < .001$) and between the Questionnaire and the Questionnaire micro (0.89, $p < .001$) as well as between Recall total and Recall Macro (0.88, $p < .001$) and Recall and Recall micro (0.93, $p < .001$). In the causation text high correlations exist between the

Questionnaire and Questionnaire Macro (0.79, $p < .001$) and between the Questionnaire and the Questionnaire micro (0.89, $p < .001$) as well as between the Recall and Recall Macro (0.92, $p < .001$) and Recall and Recall micro (0.80, $p < .001$). And this was expected.

In the sequence text, a moderate correlation exists between Recall micro and Questionnaire micro (0.46, $p < .01$) as well as between Recall Macro and Questionnaire Macro (0.53, $p < .001$); the correlation between Questionnaire Macro and Questionnaire micro is also moderate (0.50, $p < .01$), which was expected. In the causation text, the correlation between Recall micro and Questionnaire micro is very low (0.24) whereas between Recall Macro and Questionnaire Macro a moderate correlation holds (0.45, $p < .01$). The correlation between Questionnaire Macro and Questionnaire micro is moderate (0.42, $p < .01$), which was expected. H_2 had predicted high correlations between both Recall micro and Questionnaire micro, and Recall Macro and Questionnaire Macro and a moderate correlation between Questionnaire micro and Questionnaire Macro for both texts. It was not confirmed.

As far as Domain Knowledge (DK) is concerned, in the sequence text, moderate correlations exist between domain knowledge and each of the following: the Questionnaire total (0.46, $p < .01$), the Questionnnaire micro (0.52, $p < .01$), Recall (0.35, $p < .05$) and Recall micro (0.36, $p < .05$). In the causation text, moderate correlations hold only for Domain Knowledge and Recall (0.37, $p < .05$) and for Domain Knowledge and Recall Macro (0.37, $p < .05$).

Domain Knowledge is moderately correlated with Recall in both texts. H_5, an exploratory hypothesis, had predicted moderate to high correlations between domain knowledge and all of the other variables. It was not confirmed.

Previous research with both fourth and sixth graders (Boyer, Dionne and Raymond, 1993) demonstrated that text type influences reading comprehension during a recall task. H_4 predicted that text type has an effect on recall, on problem-solving and on question-answering. Table II presents a summary of Anovas for the two independent variables in the study, text type (causation and sequence) and reading ability (strong, average and weak). These are two-factor univariate Anovas.

Insert Table II about here.

Significant main effects were obtained for reading ability and each of the dependent variables except for the problem-solving activities. Thus, all three groups of subjects were significantly different from each other.

From Table II, it can be observed that significant main effects were obtained for text type and Recall Macro ($p= 0.001$) and for text type and Recall micro ($p= 0.004$).

A significant interaction was obtained for the variable Questionnaire Macro and text X reading ability. For each text $p = 0.0000$. H_4 was not confirmed (see Table II).

Interpretation

Findings for each dependent measure and for the Domain Knowledge test will be discussed. Firstly, as predicted in the Kintsch model (1988, 1992). What the problem-solving activities measure is different from what the recall task and the questionnaire measure. No significant correlations were obtained between these activities and the other variables in the study.

Kintsch (1994, p. 299) stated that free recall and answers to text-based questions are performance measures that reflect a mixture between textbase (reproductive recall) and situation model (reconstructive recall). Thus, both tasks reflect a mixture of two levels of representation.

To reflect the reality of the Kintsch model, each text in the study was propositionalized into its micro and Macro levels. The questionnaire was included as a basis for comparison with the other variables. Each question was assigned to either the Macro or micro level depending on where its response was found in the hierarchical organization of the text. Since the same levels were involved in both the Recall and the question-answering, and since both of these measures can reflect the textbase, high correlations between them were expected but were not obtained. Thus, the Questionnaire did not measure exactly what the recall task measured and can not be substituted for it. It is interesting to note that the recall task appears to be more sensitive to the effects of text type and to Domain Knowledge than does the

Questionnaire. In fact, it appears to be a more discerning performance measure. When recalling a text, subjects are confronted with organizing information and with writing it down. During recall, it is indeed difficult to avoid using background knowledge and a particular organizational pattern as a framework for the recall itself. But when answering text-based questions, subjects can get around a lack of background knowledge and/or organizational patterning because the questions themselves contain some form of structure as well as content.

The texts used in the experimentation were written in order to maximize the chances that readers would construct good textbases from them. The greatest number of idea units recalled was 133 (out of 551 or 552) for the sequence text. In general, given the small number of idea units recalled, it is possible that sixth grade subjects were not familiar with the recall task. A practice session should have been included as it had been for the Domain Knowledge test.

The results of the present research could be used to construct a reading comprehension test for sixth grade native speakers of French. At the present time, it can be said that the problem-solving activities and the recall task appear the most feasible performance measures for inclusion in such a test. The former can account for the situation model and the latter for a mixture between textbase and situation model. As predicted in the Kintsch model, with both of these types of performance measures on a text, different levels of reading comprehension can be successfully assessed. However, the recall task is hardly practical in the classroom. A solution would be to formulate a questionnaire which can evaluate the Macro and micro levels of text comprehension as the recall task does but which would be more appropriate for sixth graders. Problem-solving activities can then be included in the questionnaire.

Notes

1. All subjects designated by their teachers as having reading problems, those with learning disabilities, those repeating grade six and those whose first language was not French were eliminated from the sample. There were 16 subjects so eliminated.

2. A pilot study in October 1994 (3 classes, 75 subjects) allowed us to establish adequate times for each of the tasks. Thus, twelve minutes were allotted for the domain knowledge test (3 minutes per key word); 10 for the reading; 20 for the recall; 55 for the questionnaire; and 20 minutes for the problem-solving activities. Since the questionnaire required the longest time, it was administered separately. In fact, there were two sessions for the experiment proper for each subject, one with a text and questionnaire and a second with the same text, which was then reread, a recall and problem-solving activities.

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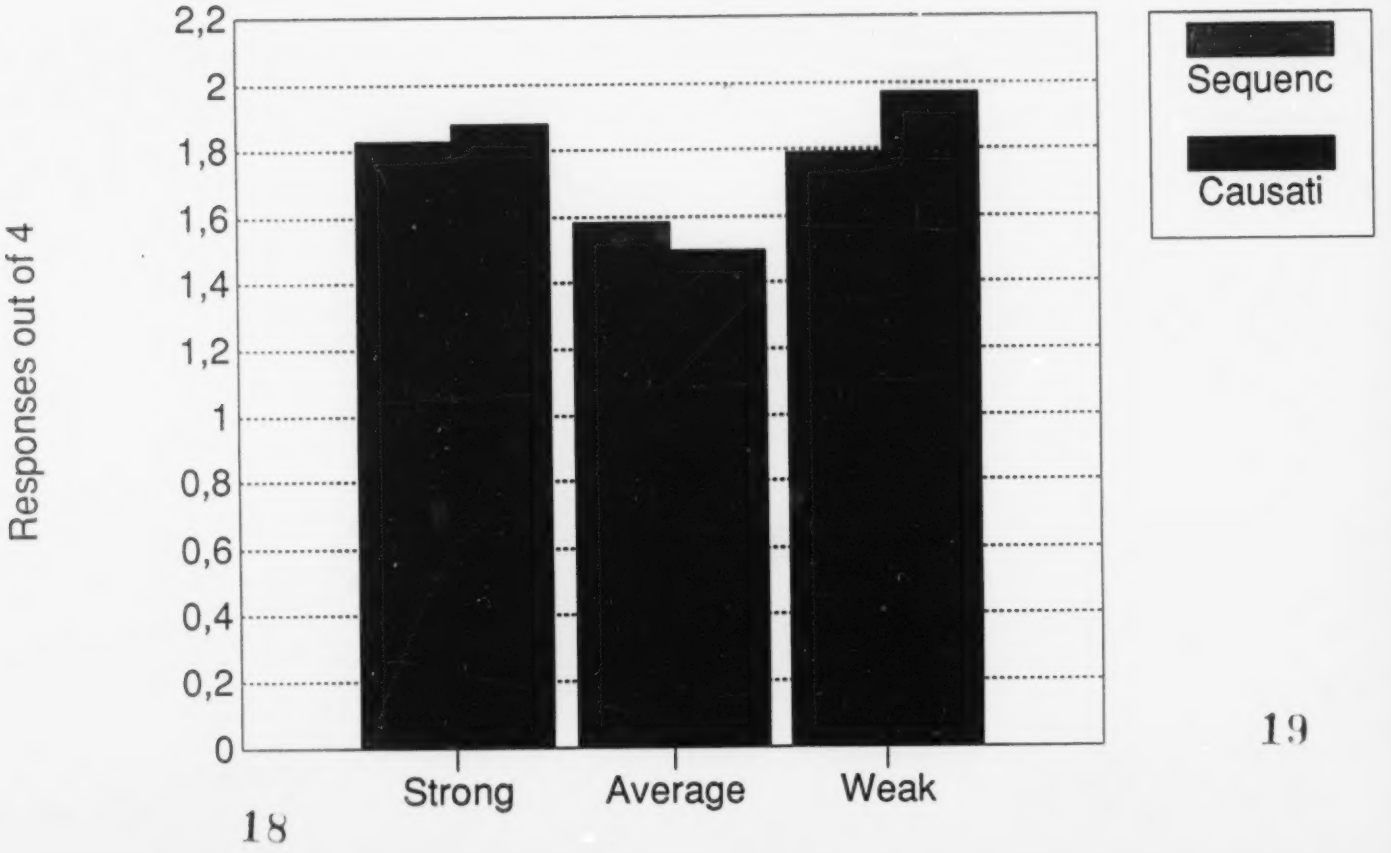
Bar graph P/S


Responses out of 4
2,2
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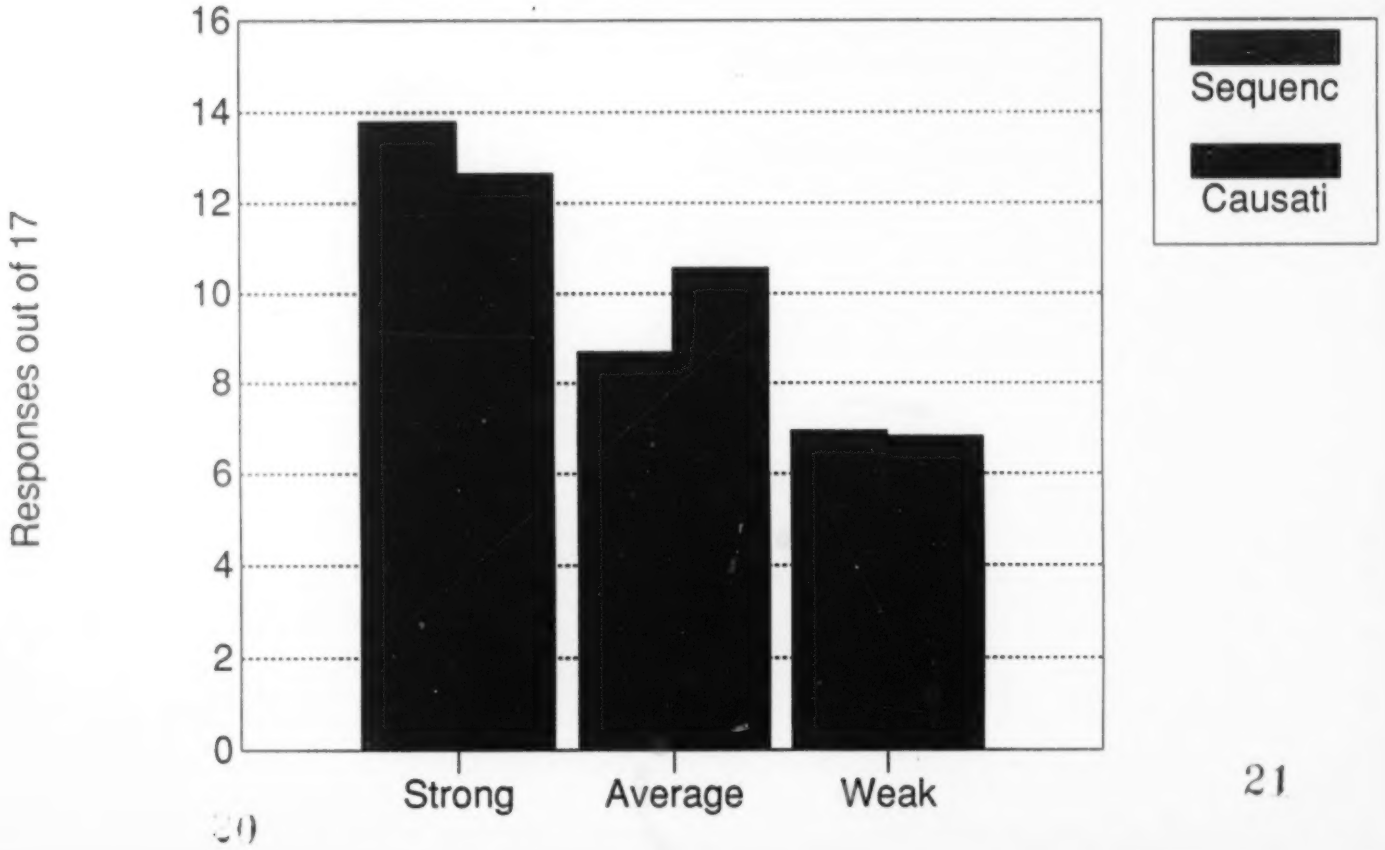
Bar graph Q


Responses out of 17
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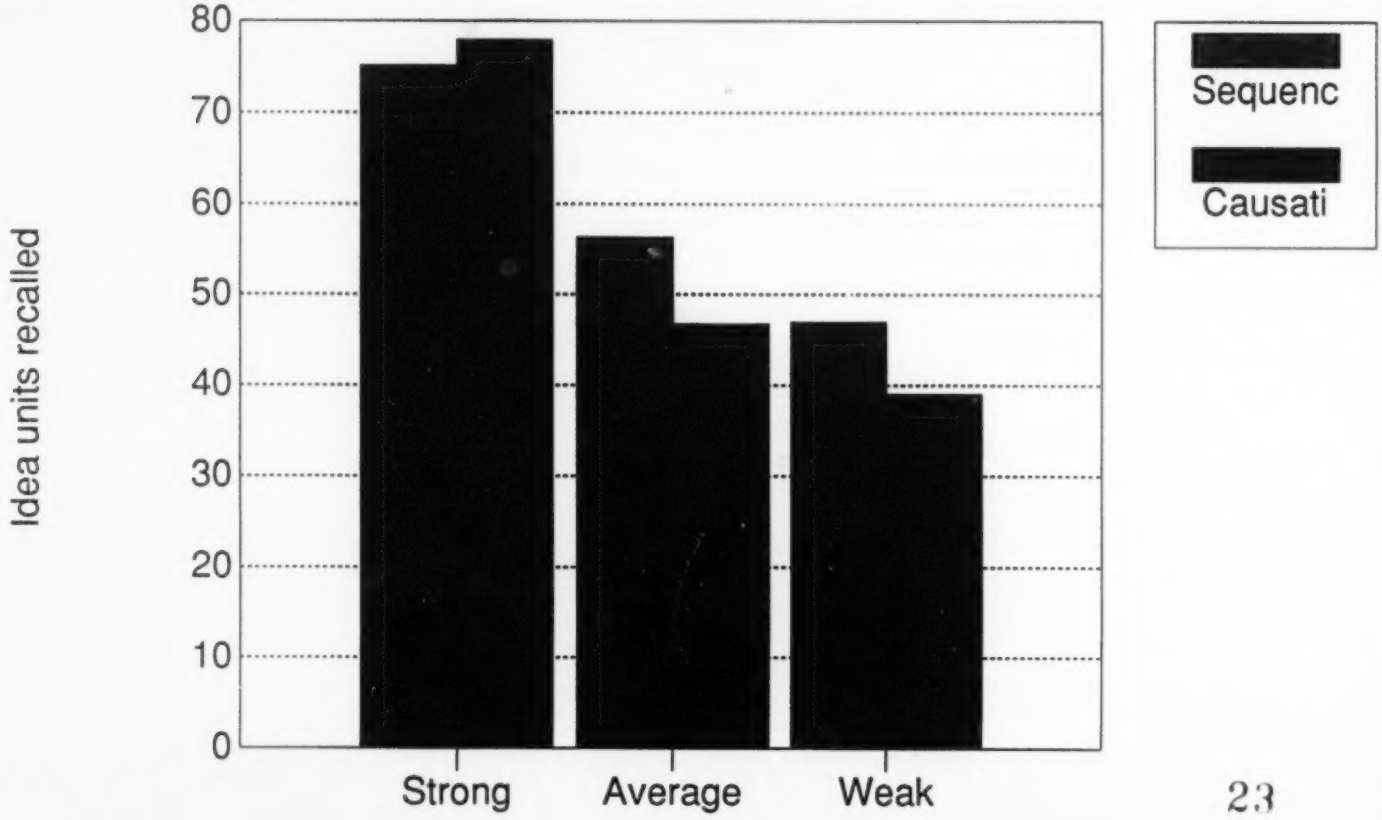
Bar graph R


Idea units recalled
80
70
60
50
40
30
20
10
0
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Average
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Causati

Table I

Matrix of Significant Correlations for All Variables for Both Texts

	RA	Q	QM	Qm	R	RM	Rm	DK	PS
Reading Abil(RA)		74[a]	61	66	35*[b]	36*	--[c]	--	--
Questionnaire(Q)	62		84	89	57	60	46**[d]	46**	--
QuestionMacro(QM)	52	79		50**	46**	53	34*	--	--
Questionmicro(Qm)	53	89	42*		53	51**	46**	52**	--
Recall total(R)	47**	47**	38*	41*		88	93	35*	--
Recall Macro(RM)	45**	52	45**	43*	92		65	--	--
Recall micro(Rm)	36*	--	--	--	80	50		36*	--
Domain Know(DK)	--	--	--	--	37*	37*	--		--
Problem-sol.(PS)	--	--	--	--	--	--	--	--	

UPPER DIAGONAL FOR SEQUENCE TEXT
LOWER DIAGONAL FOR CAUSATION TEXT
a-The two digits are to be read as 2 decimal places. All correlations above .52 are significant at the $p < .001$ level.
b-* stands for $p < .05$
c- correlations of .30 and below are represented in this manner
d-** stands for $p < .01$

Table II
Summary of Anovas

Dependent Variable	Independent Variable	*df*	*F*	*p*
Questionnaire	text	1	0.15	0.697
	ReadAbil.(RA)	2	37.04	0.000
Quest. Macro	text	1	0.12	0.726
	RA	2	23.46	0.000
Quest.micro	text	1	0.07	0.791
	RA	2	21.65	0.000
Recall (total)	text	1	0.69	0.409
	RA	2	9.97	0.000
Recall Macro	text	1	10.95	0.001
	RA	2	8.69	0.000
Recall micro	text	1	26.12	0.000
	RA	2	5.81	0.004
Problem-solving	text	1	0.05	0.831
	RA	2	1.28	0.283